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Wood and Energy in Rhode Island

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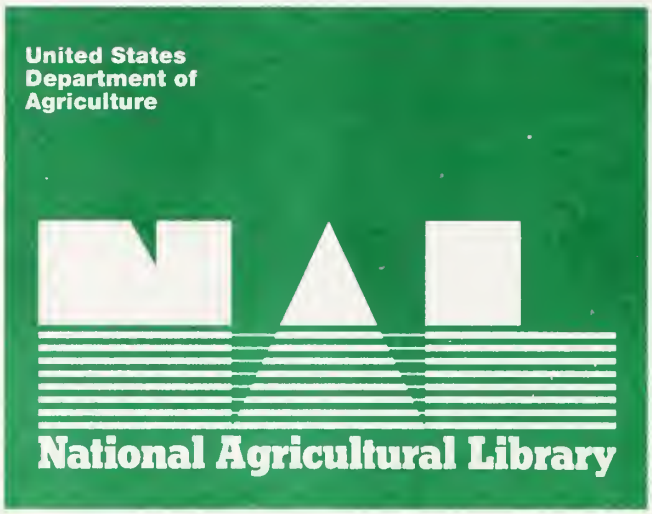
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ABSTRACT

Telephone surveys of Rhode Island households conducted in 1979 indicate a transition to wood heating in response to a series of conventional energy price increases and uncertainty in conventional energy supplies. Rhode Island households consumed 108,000 cords of wood in the winter of 1978-79. The airtight wood stove is becoming the most commonly used wood-burning apparatus. Survey data of residential wood cutting, purchasing, and burning were analyzed by household tenure, wood-burning apparatus, and county. Residential use of wood for energy constitutes a new demand on the forest resource, increases local income and employment, displaces fuel oil and electricity, but may compromise household safety.

Key words: Rhode Island, wood energy, residential energy demand, forest resource, wood-burning stoves, cordwood, fuelwood, renewable energy, energy substitution, New England.

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DEDICATION

This report is dedicated to John H. Miner, who from 1976 was the Chief, Resource Conservation and Development Branch of the Soil Conservation Service, USDA. Mr. Miner, who retired from the Service in December 1980, was an ardent supporter of the Resource Conservation and Development Program, and was especially supportive of the New England Fuelwood Study of which this report is a part.

PREFACE

Wood and Energy in Rhode Island is the sixth of a series of reports stemming from the New England fuelwood study initiated on October 1, 1978, by the Economic Research Service (ERS) at the request of a number of resource conservation and development (RC&D) areas located throughout the region (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut). These RC&D areas wished to have an economic analysis of the feasibility of using wood as an alternative energy source and an estimate of the impacts of wood energy on the State economies. Four objectives were established:

1. Analyze wood energy supply and demand.
2. Determine Btu costs of alternative fuels.
3. Identify and examine present and potential barriers to adoption of wood energy.
4. Examine the economic impact of wood energy adoption upon State economies in New England.

After conducting a literature review (6), the researchers decided to examine only the residential sector because, while there was a growing body of information regarding wood energy used in the commercial and industrial sectors, there was little regionally consistent information regarding residential use of such energy. The study was a highly cooperative effort that included ERS, the RC&D program administered by the Soil Conservation Service (SCS), local RC&D areas, State energy offices, and many other local agencies.

Wood and Energy in Rhode Island presents information on residential use of wood energy obtained from a household survey conducted in 1979 which obtained detailed information from more than 300 households. The Rhode Island survey confirms that a broadly based transition to cordwood use has occurred in household heating (fuelwood is used interchangeably with firewood and cordwood in this report). This energy shift has significantly changed the use of conventional energy and added to demands placed upon forests.

Interviewing for the Rhode Island fuelwood survey was coordinated and supervised by Paul Dolan, Marketing and Utilization Forester of the Division of Forest Environment. The survey was sponsored by the Rhode Island Division of Forest Environment and the Governor's Energy Office. The survey was conducted using the representatives from participating RC&D areas, and various State energy offices. RC&D areas and State energy offices sponsored the surveys in Maine and Connecticut. The Vermont Energy Office and the New Hampshire Governor's Council on Energy sponsored the surveys in their States. The Berkshire-Pioneer RC&D area conducted the surveys in Massachusetts.

The New England fuelwood surveys were conducted under strict guidelines. To insure reliable results, estimation techniques included a carefully prepared questionnaire, a three-way stratification of results, and rigorous testing for seven different forms of response bias. The surveys were conducted by the above noted agencies within each State which compiled and organized the data. These agencies forwarded the data to ERS for analysis. New England is now the only U.S. region with detailed and comparable State-by-State information on the residential use of wood energy and the resulting displacement of conventional energy sources.

ACKNOWLEDGMENTS

The survey of household wood use in Rhode Island would not have been possible without the energy and concern of Paul Dolan. Major contributions were also made by Lester Stillson, the former deputy State Conservationist for Rhode Island, Don McArthur, formerly the Rhode Island State Conservationist, and Robert Ericson of the Rhode Island Governor's Energy Office.

Appreciation is also tendered the following individuals who provided many helpful suggestions and assistance in the development of the study and in the preparation of this report: John Wenderoth, Cliff Jones, Robert McKusick, Ted Cady, Joseph Barse, Sheryl Davies, Beth Green, Charles Taylor-Brown, Daniel Vining, William Crosswhite, Dwight Gadsby, Anthony Grano, John Hostetler, James Sayre, Debra Ritter, Neal Kingsley, Francis Holt, Roy Mac Gray, Jeff Anliker, Donald Jones, Kay Wilhelm, Helene Blank, Frances McDevitt, Jim Bethune, Stephen Broderick, Melvin Cotner, Velmar Davis, Jerry Jolly and Robert Francis.

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HIGHLIGHTS

Most Rhode Island residents have experienced sharp increases in home heating costs since 1974 and, as a result, many installed wood-burning stoves or central wood-fired heating systems. Major findings of this study are:

* Over 108,000 cords of wood were burned by Rhode Island households during the 1978-79 winter.

* Over 6 percent of all Rhode Island households and 11 percent of owner-occupant households used wood-burning stoves or central wood-fired heating systems during the 1978-79 winter.

* Wood energy supplied 6 percent of all energy demanded by Rhode Island residents. This energy was converted into about 1 trillion Btu's of residential space heat.

* By substituting wood, Rhode Island residents displaced $9 million in petroleum and almost $1 million in electricity. Residents spent approximately $5 million of these savings on the purchase of cordwood.

* Residents relying upon the more expensive conventional home heating fuels were more likely to have installed wood-heating equipment than those who have access to a less expensive fuel.

* Homeowners who used airtight wood stoves burned approximately 1.7 cords per household during the winter and estimated that they derived 37 percent of space heat from wood.

* Residents using wood stoves were more likely to make energy conservation improvements and were more likely to lower thermostat settings than those not burning wood.

* Purchased wood supplied 37 percent of the cordwood obtained for the 1978-79 winter. Although a majority of cords were cut by household residents for their use, 47 percent of wood-burning residents purchased some portion of their wood.

* Splitwood constituted 83 percent of cords purchased. Eighty-seven percent of cords purchased were hardwood; 81 percent of purchased fuelwood was delivered.

Wood and Energy in Rhode Island

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INTRODUCTION

Since the 1973-74 oil embargo, Rhode Island households, like those in the other New England States, reacted to the resulting energy crisis by substituting wood energy for fuel oil and electricity. This transition from conventional energy sources to wood energy resulted in the burning of 108,000 cords of wood by households during the winter of 1978-79 (table 1). Increased fuelwood consumption resulted in larger demands upon the forest resource, displacement of fuel oil and electricity, and an increase of energy dollars spent in local economies.

This report describes Rhode Island families' use of cordwood, volumes of fuelwood burned, trends in fuelwood use, and the relationship between fuelwood cut and the forest resource.

REASONS FOR THE TRANSITION TO WOOD

Wood was the major energy source in New England until the early 1900's. Forests covered only 20 percent of the land area by the mid-1800's, due to the need for farmland. As the population grew, demand for wood for building and fuel continued to grow, outstripping supply by the latter half of the 1800's. Fuelwood deficits were made up by imports from the Canadian Maritime Province (1). (Underscored numbers in parentheses refer to items in the references). Demand for fuelwood peaked during the late 1800's, and coal became more and more popular. Demand for fuelwood declined precipitously after widespread adoption of petroleum-burning furnaces. Forest acreage expanded as demand for wood energy declined and the region's economy shifted to manufacturing, idling much agricultural land, which reverted to forest. By 1970, forestland encompassed nearly 80 percent of the land in the region.

Fuel oil prices, in constant 1972 dollars, have increased approximately 240 percent in New England since the 1973-74 oil

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Bailey, an ERS agricultural economist, is the New England Fuelwood Study Leader. Wheeling, formerly with ERS, was the deputy leader of the study. Lenz is an economic and statistical assistant with ERS.

Table 1--Residential wood use in Rhode Island by household groupings during the winter of 1978-79

Household group 1/	Households in wood use group	Volume of wood burned 2/
	Number	Cords 3/
Owner-occupant	201,787	89,652
Not burning wood	135,378	--
Using only fireplace	44,009	48,031
Using open wood stove	7,198	12,917
Using airtight wood stove	13,763	21,552
Using a wood furnace	1,439	7,152
Rental-occupant	146,611	12,172
Not burning wood	136,513	--
Burning wood	10,098	12,172
Second and seasonal homes	9,885	6,650
Not burning wood	3,707	--
Burning wood	6,178	6,650
Total	358,283	108,474

1/ Household classifications are stratified by tenure categories which indicate owner-occupied dwelling units, rental occupied dwelling units, and second and seasonal dwellings, which may not be occupied throughout the year. Stratification by tenure allows use of census data to control the estimate for different telephone answering rates.

2/ Estimates of the volume of wood burned are reduced 17% from volume reported by respondents to correct response bias. Major forms of response bias identified by subsurvey and resurvey are under-reporting of not-at-home households, and over-reporting of the volume burned due to imprecise knowledge of the cord measure.

3/ The term cord has traditionally referred to a stack of wood 4 feet high, 4 feet deep, and 8 feet long.

embargo and the 1978-79 winter. Petroleum accounts for over 75 percent of the energy used in New England, and over 75 percent of the petroleum consumed is imported from foreign sources. Petroleum accounts for 60 to 70 percent of the energy consumed in Rhode Island and between 55 and 65 percent of conventional energy demanded by residences. Heating requirements of a Rhode Island household are 124 percent of the national average. As a result, Rhode Island residents have keenly felt the increasing cost of home heating, and their desire to lower heating costs has been a central factor contributing to the transition to wood heat.

TRANSITION TO CORDWOOD USE IN RHODE ISLAND

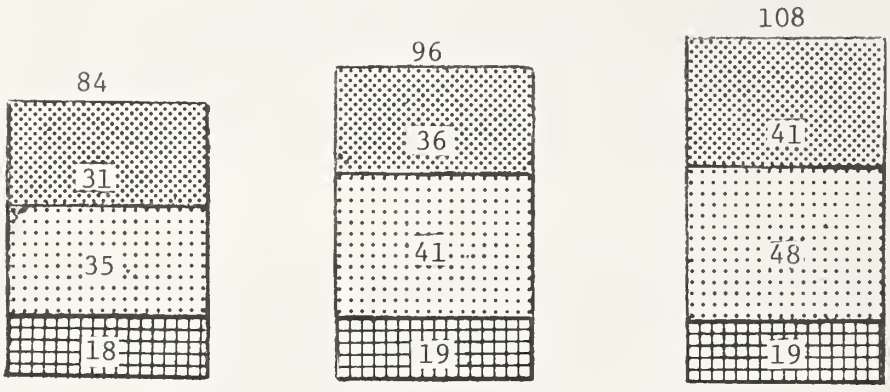
Use of wood heat in Rhode Island in 1970 was well above the national average which was less than 1 percent of homeowners (6). Still, very few of the State's homeowners used wood-heating appliances, and much less heat was provided per wood-burning stove. During the 1978-79 winter, 11 percent of Rhode Island's homeowners used wood-fired heating equipment as either their primary or supplementary source of space heat.

Trends in Residential Wood Use

Estimates of the volume of wood burned in residences during the winters of 1976-77 through 1978-79 were developed from the 1979 Rhode Island fuelwood survey. Trends in residential wood use (the fuelwood volume differences between the surveyed winter and the previous winters) are primarily estimated from when wood-burning equipment was installed and the type of equipment, if any, used prior to that date. The annual increase has averaged 14 percent over 1976-77 to 1978-79 (fig. 1). Of the 250 owner-occupant households responding to questions in the survey, 7.6 percent used a wood stove during the winter of 1978-79. Almost all of these stove users used a wood stove during the previous winter (7.2 percent of all owner-occupant households). Approximately 1 percent of homeowners used a central wood furnace prior to and during the winter of 1978-79.

The Rhode Island survey, as well as the other New England State surveys, gives no indication that the increase in wood use will not continue, especially if the relative costs of conventional fuels continue to rise. Further, the surveys do not record the recent increase in wood use which may have resulted in response to the 1981 petroleum price decontrol and subsequent rises in fuel oil and kerosene prices (Massachusetts has conducted a 1982 follow-on survey to estimate this effect).

Figure 1--Trend in residential wood use, three winters, 1976-1979, Rhode Island, Thousands of cords



1976-77 1977-78 1978-79

percentage increase 1976-77 to 1977-78	percentage increase 1977-78 to 1978-79
17 percent	11 percent

Volume of wood burned by homeowners using wood stoves or wood-fired central heating systems.
Volume of wood burned by homeowners using fireplaces.
Volume of wood burned in rental households and second homes

The rational response to increasing conventional heating fuel prices indicated by the survey findings implies that an increase in wood energy use will occur if and when natural gas is decontrolled (assuming a price increase will result). As the costs of conventional energy rise relative to the cost of wood energy, more households will substitute wood energy.

Prior to the oil embargo of 1973-74, fuel oil was relatively low in price and, as a result, most residences in Rhode Island were heated by that energy source. During the same pre-embargo period, the marginal cost of wood-supplied heat was higher than fuel oil-supplied heat, and most cordwood was burned for aesthetic purposes rather than as a substitute for conventional energy. The increases in fuel oil prices that followed the 1973-74 petroleum embargo, however, had a profound impact upon the use of wood for energy not only in Rhode Island but in all of New England as well.

Consumers realized that even with the increased prices of fuel oil, the nonairtight stoves that dominated the market were too inefficient to make wood energy competitive with conventional energy. As a result, more efficient stoves were designed and built and the users were able to extract more energy per pound of wood burned. The increased efficiency made wood-supplied heat significantly lower in price than that supplied by fuel oil. A very high proportion of the stoves installed since 1974 have been of the efficient airtight type (table 2). The increased wood-burning efficiency of such stoves made the marginal cost of wood less than that of fuel oil and, as a result, the average amount of wood burned in airtight stoves increased. Compared to those households that use inefficient, nonairtight stoves, those using airtight stoves typically burn 12 percent more wood per year and derive a greater amount of heat. Rhode Island households are consequently experiencing greater displacement of fuel oil and electricity, as well as larger savings in heating costs.

Table 2--Proportion of various wood-buring apparatuses installed in Rhode Island

Period installed	Open wood stove	Airtight stove	Wood furnace
		Percent	
Before 1974	100	0	0
1974-76	36	64	0
1977-79	25	58	17

Future Use of Wood for Energy

Future residential demand for wood energy is a vital matter to those concerned with forest resource management, energy planning, air quality management, forestry-related employment, and wood stove manufacturing. Reliable projections of wood energy demand are now impossible because changes in major

influences on wood use, which include prices of fuel oil, electricity, and natural gas, cannot be predicted. However, relationships identified in this analysis point to at least six factors having influence on the use of wood energy: relative cost of energy, perceived problems with wood use, excess demands on the forest resource, air pollution abatement regulations, increased home insurance rates, and State liability laws.

Relative Cost of Energy

The most influential factor on future demand for wood energy is the change in relative costs of heating with alternative fuels. Three survey findings substantiate this conclusion:

1. Residential household use of wood-fired heating equipment is disproportionately concentrated in those households displacing more expensive heating fuels. For example, 20 percent of the Rhode Island homeowners using electricity as a conventional fuel use wood heat. During 1978, fuel oil and natural gas were only 35 and 36 percent of the cost of electricity per Btu of heat provided (table 6). The rate of use of wood heat by homeowners using fuel oil as a conventional fuel was 12 percent. For natural gas users, the rate was only 3 percent.

2. A greater percentage of New England homeowners use wood heat in areas of relatively low cordwood prices.

3. The installation rate of wood-fired heating equipment has paralleled increasing petroleum prices.

Increases in the relative price of fuel oil, electricity, and natural gas will likely spur an increase in wood use. At the same time, increases in the relative price of cordwood would decrease wood use by households purchasing wood. There is a huge latent wood energy demand in industries that could convert to wood-fired boilers, including electrical utilities and alcohol plants. If such demands were realized, the relative price of wood energy could increase and approach that of conventional energy. Then, other alternative energy sources, particularly coal and solar, would become more competitive.

Perceived Problems with Wood Use

Growth of residential wood use has been somewhat dampened by several problems which nonwood-burning households presently associate with wood use. Such homeowners most frequently identify potential hazards of burning wood as the major reason why they do not use wood (table 3). Renters identify problems concerned with getting permission from the landlord, cost of the stove, and locating adequate cordwood supplies.

Table 3--Perceived problems with wood use by owner-occupant households not burning wood, 1979, New England

Perceived problem	Rhode Island	Maine	New Hampshire	Vermont	Massachusetts	Connecticut
			Percent 1/			
Time and effort in cutting wood	6	24	19	10	20	45
Price of fuelwood	4	32	23	8	15	53
Locating adequate supplies to purchase or cut	3	21	13	4	9	35
Potential hazards of burning wood	47	38	56	66	49	34
Cost of stove	5	37	13	4	13	27
Inconvenience in handling	21	11	26	29	20	0
			Number			
Sample base	150	229	247	86	779	83

1/ Percentages do not add to 100 since more than one reason was often given by each respondent.

Excess Demand on the Forest Resource

Residential long-term fuelwood demand on the forests in Rhode Island is but a small fraction of the State's renewable resource base. Present residential fuelwood demand amounts to only 2.4 percent of the existing volume of forest stock (and this assumes that none of the demand is satisfied by imported fuelwood). Present timber industries' demands amount to a very insignificant portion, if any, of the existing stock. Although there are areas in New England utilizing cordwood at levels above sustainable yield, shortages have not occurred because of large standing stocks and importation.

The question as to whether the State's resource base can satisfy the multitude of long-term demands is difficult to assess due to the present condition of the forest resource, land ownership patterns and land ownership objectives. Large and dense standing stocks can provide an adequate supply

for many years, and as a result, current harvesting can be well above sustainable yield without seriously impairing the renewability of the resource. All demands are currently being met, and should be in the foreseeable future. However, the State may wish to develop a monitoring program to provide an early warning if future harvestings should begin to seriously erode the forest resource ability to provide future supplies, not only to the residential sector and the timber industry, but also to wildlife and recreational interest.

However, if current demands continue, and as the over-stocked and relatively poor quality wood resource is harvested, cordwood prices and the potential of overcutting may rise. Given the present lack of relevant data concerning the forestry supply and demand relationships, definitive statements cannot be made regarding the time period when excessive demands may begin to adversely affect the forest resource. In addition, land holding patterns and ownership objectives usually permit current cordwood harvesting by landowners. In the longer term, however, these same ownership patterns and landowner objectives may limit future availability.

Potential Pollution Regulations

Increased wood burning has raised pollution levels to the point that some areas now control the use of wood energy (Portland, Oregon and Vail, Colorado). Topographical characteristics of Rhode Island, as well as the other States in New England, together with increased burning of wood, have also resulted in locally increased ambient pollution levels. As use of wood for energy continues to increase, degradation of air quality may result in environmental controls and public awareness that could limit increases in household use of wood for energy.

Home Insurance Policy Premiums

More house fires have occurred as the use of wood energy has increased. While the majority of house fires associated with fuelwood use results from improper installation of wood-burning equipment, a number of such fires are a result of chimney fires. The chimney fire problem is further exacerbated by the increasing number of airtight stoves. Maximum stove efficiency is a function of adequate oxygen, fuel, and burning temperature. Too much air results in excess heat going up the chimney; too little air results in a cooler fire, a cooler flue, and an increase in creosote (condensed gases) production. Many households operate airtight stoves with too little air which, while extending the period between reloadings also increases creosote formation. Creosote buildup increases the potential of chimney fires and related house fires. This problem can be minimized by cleaning the chimneys

and letting the stove burn hot for specified periods on a regular basis as recommended by manufacturers.

A number of insurance companies will not issue household insurance premiums to mobile homes using wood stoves. Many insurance companies are comtemplating a supplementary premium for houses that use wood stoves if the incidence of house fires resulting from the operation of wood-burning apparatuses increases much further. Such premiums could dampen the demand for new equipment and fuelwood.

State Liability Laws

State liability laws may constrain wood cutting. Prior to the resurgence of cordwood use, owners of forestland may have been liable for injuries received by individuals cutting wood on their land. As a result, many landowners did not permit individuals to cut wood on their property, and thus accessibility to fuelwood sources was limited. Some New England States have countered this legal constraint by implementing legislation limiting homeowner liability if cordwood stumpage is given away.

WOOD CONSUMPTION AND ENERGY CONSERVATION BY RHODE ISLAND HOUSEHOLDS

Rhode Island families have responded to increasing heating costs and uncertain energy supplies by adopting fuelwood heating, making heat conservation improvements, and changing thermostat operations (lowered settings, zoned heating, and timed heating).

Residential Use of Wood for Energy

Rhode Island families burned 108,000 cords of fuelwood during the 1978-79 winter (table 1). Over 6 percent of all households and 11 percent of homeowners used a wood-burning stove or central wood-fired heating system. The increase in residential wood use recently has been about 14 percent per year, reflecting initial installations of wood-heating equipment and some upgradings of existing equipment. The substitution of wood energy has resulted in a more healthy State economy because dollars that would have been spent on imported oil remain in the State to be spent on local goods and services, including locally produced fuelwood. More information on the economic impacts of wood energy substitution appears in a forthcoming report. 1/

1/ Mark R. Bailey, Paul R. Wheeling and Maria I. Lenz. "Wood and Energy in New England: A Regional Perspective," New England Fuelwood Study. Econ. Res. Serv., U.S. Dept. of Agr. Forthcoming.

Patterns of Cordwood Use

The primary stress on fuelwood resources is not due to rural wood stove use. Intensity of fuelwood use per unit of land area is largely determined by population; thus, areas with more households generally burn a larger total volume (table 4 and fig. 2).

Table 4--Volume of cordwood burned in Rhode Island households, by county, winter, 1978-79

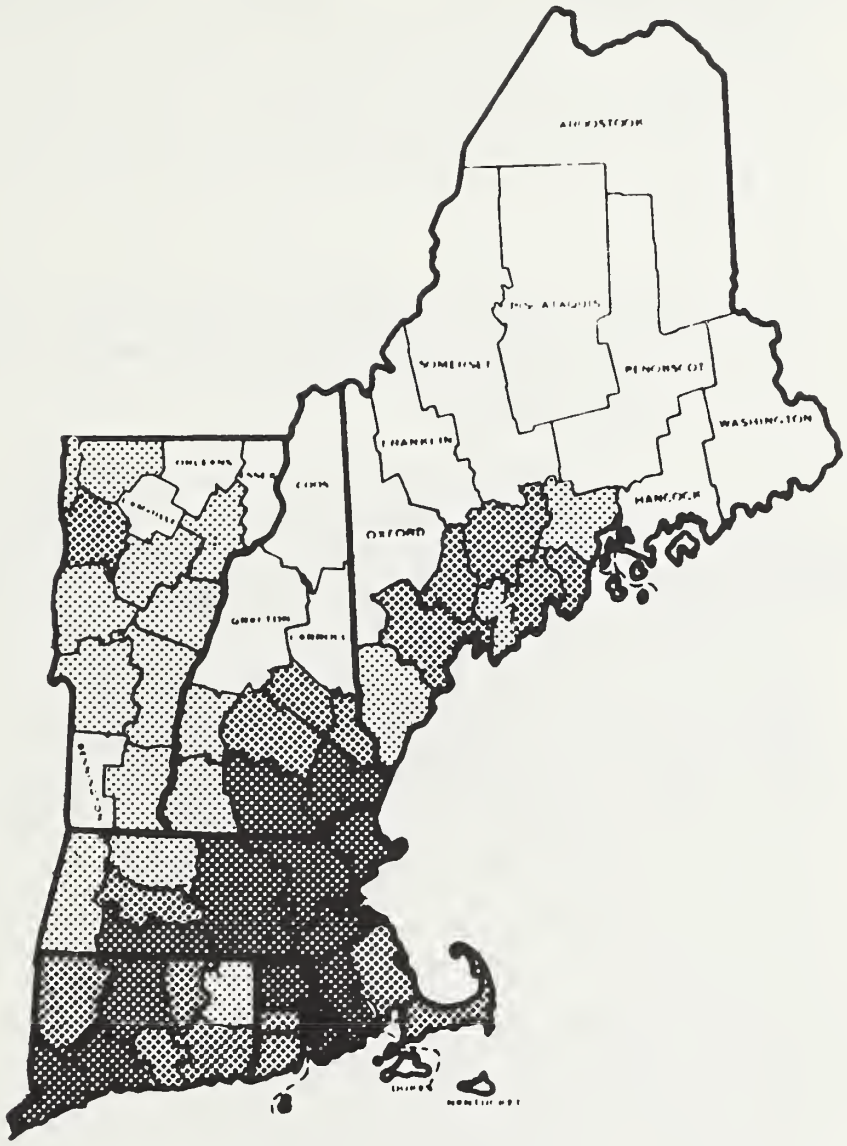
County	Volume burned	Percentage of State total
	Cords	Percent
Providence	51,852	48
Washington	20,497	19
Kent	17,133	16
Newport	12,087	11
Bristol	6,904	6
Total	108,474	100

Impact of Wood-Burning Equipment on Cordwood Use

There are a variety of wood-burning appliances, ranging from traditional open wood stoves to relatively sophisticated airtight stoves and central wood-fired heating systems. Of the 66,000 Rhode Island homeowners using wood-burning appliances in 1979, 1,000 used central wood-burning furnaces, 14,000 used airtight wood stoves, and 7,000 used open wood stoves. Almost one quarter of the wood consumed by households in Rhode Island was burned in airtight wood stoves.

Rhode Island had a much higher incidence of fireplace use than did the Northern New England States. Fireplaces consumed over one-half of the wood burned by residences. However, as in Northern New England, this market is expected to decrease as fireplace users switch to more efficient airtight wood stoves.

Figure 2--Intensity of residential demand for fuelwood, 1978-79, New England



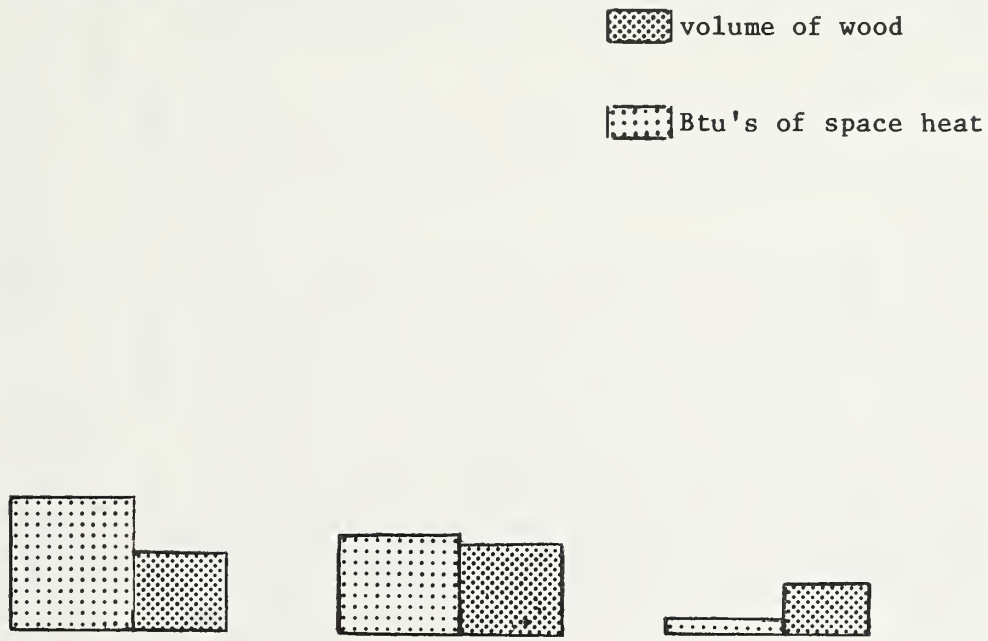
The average number of cords a household is likely to burn, and the number of Btu's that may be expected, depends on the type of apparatus used (fig. 3). Households in Rhode Island using airtight wood stoves, burned an average of 1.7 cords of wood during the 1978-79 heating season. The actual volume burned over a winter varies greatly, however, ranging from roughly 1 to 6 cords per year. Airtight wood stoves in Rhode Island provide an average of 20 million Btu's of available space heat per household during a winter, assuming a 50 percent operating efficiency.

Such a stove could provide about one-fourth of the heating requirements of a home requiring 90 to 100 million Btu's of space heat per year. Rhode Island homeowners, however, estimate that their airtight wood stoves provide 37 percent of space-heating needs (table 5).

In all the New England States except Rhode Island, survey respondent estimates of the proportion of space heat provided by wood were significantly higher than estimates derived by calculating the amount of conventional energy displaced by the volume of wood burned. Owner-occupant residents using both an airtight stove and an oil-fired central furnace consistently reported conventional fuel cost reductions that reflect a greater than one-for-one value of wood heat substitution. This difference may be due to a lack of information on the amount of useful energy which a household can derive from a cord of wood. Also, residents installing and operating wood-burning equipment may use less energy than they previously used and wood-burning equipment may provide a quality of heat that results in less demand for fuel. Resident estimates in Rhode Island equaled that calculated through estimating the conventional Btu's displaced by wood energy (table 5).

The wood-burning apparatus heavily influences the magnitude of fuelwood consumption and conventional fuel savings. The airtight wood stove, which has recently dominated installations, shows a consistent pattern of wood consumption per household across most New England States and from year-to-year in Rhode Island. Once installed, characteristics of the wood stove and its placement largely determine the volume of wood burned and conventional energy displaced. A subsequent increase in the cost of the conventional fuel does not generally result in a significant change in the volume of wood burned in wood stoves already installed. Of course, the

Figure 3--Average volume of cordwood burned and available heat per household, by type of apparatus used, winter, 1978-79, Rhode Island



volume of wood burned by a household is influenced by access to fuelwood, cost of the fuel displaced by wood at the time of the installation, housing type, and the extent to which the home is insulated. Newly developed apparatuses which increase wood-burning efficiency (e.g., the forced-air stick furnace and designs incorporating catalytic converters) may change fuelwood demand.

Cost Relationships of Conventional and Wood Energy

Information on relative costs served as a base in analyzing the household decision to use wood heat. The price differential between purchased wood and fuel oil in Rhode Island resulted in heat provided by fuel oil costing 95 percent of that provided by wood in 1978 and costing 155 percent of heat

Table 5--Wood-burning characteristics averaged for owner-occupant households, by apparatus type, winter, 1978-79, Rhode Island

Apparatus	Wood burned	Available heat 1/	Estimated savings in conventional fuel 2/	Homeowner estimate of percentage of heat from wood 3/	Average daytime thermostat settings 4/	Efficiency assumed for study
	Cords	Btu x 10^6	Dollars	Percent	Degrees	Percent
Open fireplace	1.1	1	56	8-10	66	5
Efficient fireplace	1.0	4	250	12-28	67	15
Traditional wood stove	1.9	11	163	20-35	64	30
Airtight wood stove	1.7	19	241	37-37	63	50
Wood furnace (combinations incl)	-	-	-	-	64	55

Note: - = insufficient sample reported.

1/ Available heat calculated from an estimated 24 million Btu's per cord times average number cords burned, times assumed efficiency of wood-burning apparatus.

2/ Based largely upon fuel oil costing 55 cents per gallon. Savings are an average of homeowner estimates.

3/ Values on left side calculated from estimates of dollar savings and cost of conventional fuel; values on right side estimated as a percentage by respondent.

4/ Estimated thermostat settings determined by the New Hampshire Fuelwood survey based upon data provided by the New Hampshire Governor's Council on Energy for similar household groups in New Hampshire.

provided by wood in 1981 (table 6). Households using more expensive energy sources have a greater tendency to install wood-burning equipment than households using less expensive energy sources.

These patterns of relative cost and tendency to install wood-burning equipment indicate that household decisions resulting in the use of wood heat are primarily a rational attempt to lower heating costs.

Use of Energy Conservation Measures

Rhode Island households also reduce heating costs through home improvements and thermostat operations directed at energy conservation. Improvements in existing homes may include upgrading insulation, installing storm doors and windows, caulking, and weather stripping. Changes in thermostat operations, which include lowering thermostat settings and heating less than the entire home, decrease a household's heating demand. While a wood stove may provide normal or higher than normal temperatures in a central or often used room, peripheral areas of the home may cool to the thermostat setting or lower. Lower temperatures during periods when the wood stove is not attended also may result in energy cost reductions.

Respondents addressed five specific types of energy conservation improvements. Most homeowners indicated that they had made one or more of these home improvements during the past 3 years. Although few had installed solar water heat, performed furnace maintenance, or improved caulking and weather stripping, many had installed storm windows and a majority had made insulation improvements (table 7). At least 14 percent of Rhode Island homeowners improved their insulation each year. Rhode Island homeowners using an airtight wood stove are more likely to make energy conservation investments than are homeowners not burning wood or using an open fireplace (table 7).

The total percentage of homeowners reporting conservation improvements in Rhode Island is slightly lower than in the Northern New England States. However, 18 percent more airtight stove owners reported improvements. The pattern of fireplace owners is usually consistent with or slightly lower than that of Northern New England.

Lowered thermostat settings are more likely to be found in those homes using wood heat in the more efficient burning apparatuses. Questions concerning thermostat settings were included in the resurvey of household wood use in New Hampshire,

Table 6--Relative cost of alternative heating fuels, 1978 to 1981, Rhode Island

Energy source and burner	Applicable unit	Cost/unit 1978	Cost/unit 1981	Energy per unit	Typical burner efficiency factor	Available energy	Cost/million Btu's 1978	Cost/million Btu's 1981	Relative cost per mil. Btu's 1/ 1978	Relative cost per mil. Btu's 1/ 1981
		--Dollars--		Million Btu's	Percent	Million Btu's	--Dollars--		--Percent--	
Wood, airtight stove	cord	70	105	2/ 24	50	12.0	5.83	8.75	100	100
central system	cord	70	105	2/ 24	55	13.2	5.30	7.95	91	91
Electricity, resistance	kWh	3/ .0547	4/0.08	.0034	100	.0034	16.03	23.52	274	269
Natural gas furnace	1000 cu.ft.	3/4.18	4/8.30	1.04	70	.728	5.74	11.40	99	130
LP gas furnace	gallon	3/ .349	4/ .95	.090	70	.063	5.54	15.07	95	172
#2 fuel oil furnace	gallon	3/ .502	5/1.219	.1387	65	.090	5.57	13.54	95	155

1/ Computed by dividing the energy price by the price of wood energy in an airtight stove.
2/ Btu/cord of wood weighted according to volumes of hardwood and softwood consumed in a typical residential cord.
3/ Price data from State Energy Fuel Prices by Major Economic Sector from 1960-1977 (some for 1978): Preliminary Report and Documentation, U.S. Dept. Energy, July 1979.
4/ Price estimates for 1981 from Rhode Island Civil Preparedness Office.
5/ Price estimates from Rhode Island Civil Preparedness Office, Aug. 1982.

where household characteristics of those using wood are somewhat similar to Rhode Island. New Hampshire households using an airtight wood stove reported an average daytime thermostat setting of 63 degrees and a nighttime setting of 60 degrees, several degrees lower than those not burning wood or using only a fireplace. These lower settings save an additional 10 to 15 percent of space heat.

Energy conservation improvements, lowered thermostat settings, and the substitution of wood for a more expensive heating fuel are measures which tend to occur, in combination, in certain households. This suggests that these measures are part of an overall household strategy directed at the reduction of heating costs. Households not burning wood are consistently less likely to make an energy conservation improvement (table 7).

Table 7--Owner-occupant household energy conservation improvements, by apparatus, winters, 1976-79, Rhode Island

Apparatus	Making insulation improvement	Installing storm windows	Caulking or weather stripping	Sample size
	Percent			Number
Owner-occupant household not burning wood	36	21	23	163
Owner-occupant household using an open fireplace	43	28	39	46
Owner-occupant household using an airtight wood stove	72	28	33	18
All homeowners	42	23	28	227

OBTAINING CORDWOOD IN RHODE ISLAND

Rhode Island households obtain cordwood through purchase and/or household harvesting of such wood. While wood-burning residents cut more wood than they purchased, more than 47 percent of them purchased at least some part of their cordwood. Over 80 percent of the cordwood marketed in Rhode Island is sold as splitwood. Market demand for cordwood is directly related to density of population, or more specifically, to density of owner-occupant households.

Seller services such as bucking, splitting, delivering, and stacking all influence cordwood price. Market demand for purchased cordwood will likely continue to increase since both the 1979 and follow-up surveys in the other New England States show that the percent of purchased wood burned has increased over previous years.

The bulk of cordwood harvested by residents is cut on family-owned lots attached to their residence. As a result, such harvesting is concentrated on a small portion of forestland. Harvesting by residents does not seem to be directed at improving the quality of their woodlots since a small proportion of such operations received guidance from professional foresters (table 17). The wood they cut was not suitable for producing lumber and most of the wood cut was dead, blown down, rotten, or residue from land clearing operations.

Volume of Cordwood Purchased and Cut

Rhode Island residents purchased over 69,000 cords and cut nearly 40,000 cords of wood for their own use during 1978 (table 8). During 1978, owner-occupants using a wood-burning stove or central wood-fired heating system acquired 40 percent of all wood obtained by residences even though they constituted only 6 percent of all households. As a whole, wood burners using fireplaces tend to purchase a higher percentage of their wood than those using wood stoves. In Rhode Island, where many more households use fireplaces, homeowners using fireplaces purchased about 20,000 cords during 1978, constituting the largest market group. Wood stove and furnace users purchased approximately 15,000 cords. Purchases by fireplace owners accounted for 49 percent of the total volume of firewood sold. This market outlet will undoubtedly decrease as more efficient wood-burning apparatuses are installed by those presently using fireplaces.

Considerable county-to-county differences are evident in the market demand for cordwood. The volume of wood purchased by residents in a county parallels the volume of wood burned and county population (tables 9 and 4).

Households installing stoves since 1973 have greater tendency to purchase their wood (table 10). Purchased wood accounted for 37 percent of the wood obtained by households during 1978 (tables 8 and 9). Forty-six percent of homeowners cut all of their wood, 36 percent purchased all of their wood and 11 percent both purchased and cut. An additional 7 percent acquired no wood during 1978. This final group may represent families who burn wood acquired during previous years.

In most New England States the method by which wood is obtained relates to the volume burned by households. Residents using a particular apparatus typically burn less if all of their wood is purchased rather than harvested (table 11).

Table 8--Cordwood obtained for the winter of 1978-79, by household group, Rhode Island

Household groups	Volume cut by households	Volume purchased	Total acquired	Portion purchased	Average volume purchased
	-------Cords 1/--------			Percent	Cords
Owner-occupant using fireplaces	27,600	19,600	47,200	40	1.1
Owner-occupant using wood stove or furnace	28,700	14,800	43,500	34	1.7
Other households	12,500	5,800	18,300	33	N/A
Total	68,800	40,200	109,000	37	1.5

Note: N/A = not available
1/ rounded to nearest 100.

Table 9--Cordwood obtained by households, by county, winter, 1978-79, Rhode Island

County	Method of acquisition: Self-cut	Purchased	Total acquired	Portion purchased
	----------Cords 1/--------			Percent 2/
Bristol	3,700	4,200	7,900	54
Kent	8,100	8,400	16,500	51
Newport	6,800	3,100	9,900	32
Providence	30,500	20,700	51,200	40
Washington	19,700	3,800	23,500	17
Total	68,800	40,200	109,000	37

1/ Rounded to nearest 100.
2/ Percentages calculated from nonrounded data.

Table 10--Method of obtaining cordwood, by installation date, Rhode Island

Period of wood stove installation	All wood cut by household	Wood cut and purchased	All wood purchased
		Percent	
Before 1974	0	0	100
1974-76	62	8	23
1977-79	46	27	27

Table 11--Average volume of cordwood burned by apparatus and method of acquisition, winter, 1978-79, Rhode Island

Wood-burning group	All wood cut by household	Wood cut and purchased	All wood purchased
	----------Cords----------		
Owner-occupant using a fireplace	1.3	1.3	1.0
Owner-occupant using a traditional wood stove	2.5	1.0	1.5
Owner-occupant using an airtight wood stove	1.9	2.3	1.3
Owner-occupant using a central wood furnace	*	--	--

Note: -- = none reporting in sample; * = insufficient sample reporting.

Characteristics of Purchased Cordwood

Purchased firewood comes in many forms: roundwood and splitwood of varying lengths, and slab and other forms of manufacturing waste. 2/ There are also a number of services (splitting, delivering, stacking) that may or may not accompany the purchase. Splitwood accounted for 83 percent of purchased wood in 1978, more than any state in New England, and 31 percent of all wood acquired. Roundwood accounted for the remaining 17 percent (table 12 and table 13).

Table 12--Volume of firewood purchased, by form and length, 1978, Rhode Island

Category	Cords purchased	Proportion of purchased wood in category	Proportion of all acquired wood in category
	Cords 1/	-------Percent-------	
Roundwood	6,800	17	6
Greater than 4 ft.	1,000	3	1
4 ft.	2,500	6	2
Less than 4 ft.	3,300	8	3
Splitwood	33,400	83	31
Greater than 4 ft.	--	--	--
4 ft.	6,000	15	6
Less than 4 ft.	27,400	68	25
Manufacturing waste and slab	0	0	0
Total	40,200	100	37

1/ Rounded to nearest 100.
Note: -- = none reported in sample.

2/ Roundwood refers to cordwood not processed by splitting lengthwise. In other reports, notably Forest Service resource reports, roundwood refers to timber used in its original form as distinguished from industrial byproducts. Thus, the Forest Service would use the term unsplit roundwood to describe this wood.

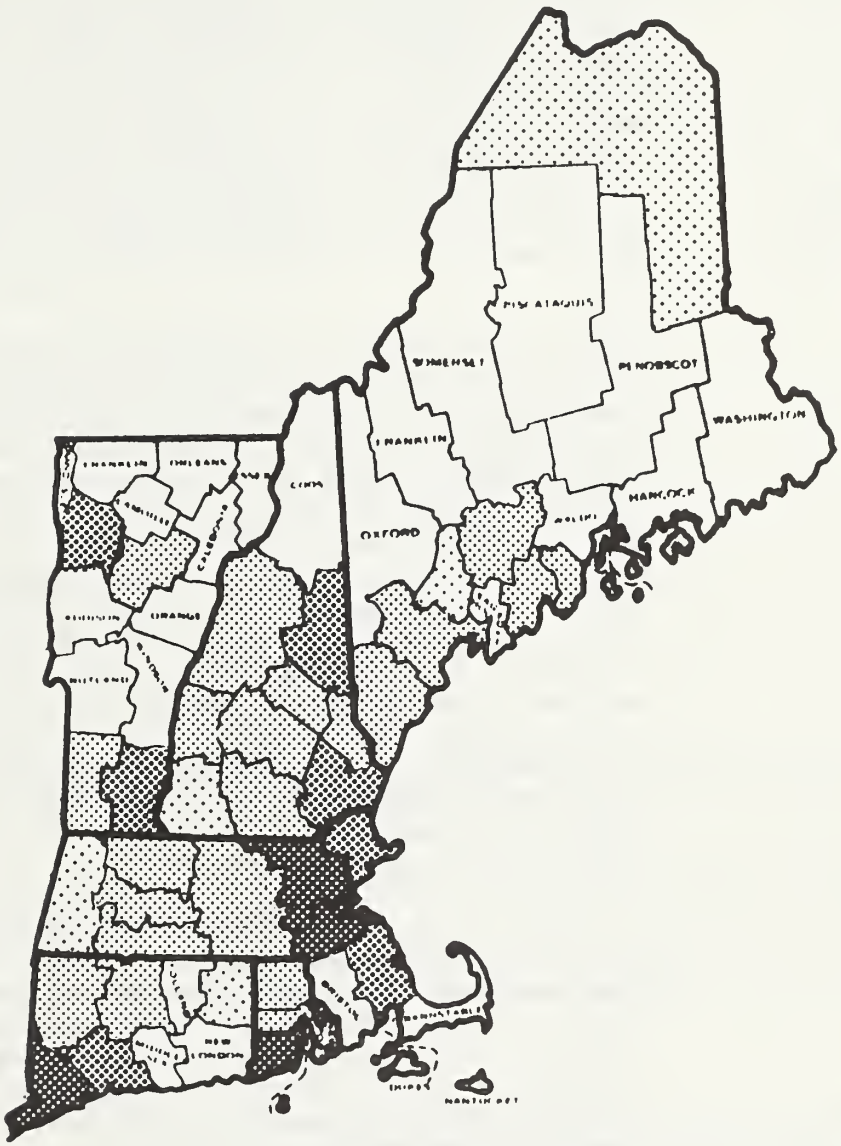
Cordwood price varies according to the number and kind of services provided. Major seller services are bucking, splitting, seasoning, delivering, and stacking. Price also varies with the size of the sale, time of year, price of conventional space heating fuel, and distance from major fuelwood harvesting operations. For example, one would expect to pay a significantly higher price for a cord of split hardwood, cut to 18-inch lengths, delivered and stacked in Boston in January than for a cord of 8-foot long roundwood delivered to a central Vermont household in July.

Table 13--Characteristics of household firewood purchases, 1978, New England

State	Purchases split	Purchases hardwood	Purchases delivered	Purchases seasoned	Purchases made early
			Percent		
Maine	35	94	81	61	64
New Hampshire	47	92	90	64	72
Vermont	58	95	93	67	62
Massachusetts	56	92	82	82	49
Rhode Island	83	87	81	75	34
Connecticut	59	85	79	81	35

During 1978 and through the winter of 1978-79, a cord of wood cut to stove length, split, and delivered cost an average of $70 in Rhode Island. Split cordwood prices varied somewhat across the State: $61 in Providence county, $66 in Kent county and $79 in Bristol and Washington counties (fig. 4). The median price was $60 for the 39 New England counties reporting sufficient samples of split cordwood prices for 1978.

Figure 4--Processed cordwood prices by county, 1978, New England
(Estimated from a 39-county sample of split cordwood prices)



$75 to $110 per cord
(area of highest cordwood price)

$62 to $74 per cord

$50 to $61 per cord

$49 or less per cord

Prices not available
(Generally high standard error
due to insufficient sample)

A more recent indication of cordwood prices is provided by a 1980-81 review of newspaper classified advertisements across New England. The price of a cord of seasoned hardwood -- cut to stove length, split, and delivered locally -- depended upon location and ranged from $70 to $125 a cord. The average price in Providence was $105. 3/

Harvesting Cordwood and Land Use Characteristics

Rhode Island families cut 69,000 cords of wood for their own use in preparation for the winter of 1978-79 (table 8). This volume represents 63 percent of the wood burned by residences. In order to assess potential impacts of this harvesting, it is first necessary to determine where these 69,000 cords were cut.

Survey information from across New England on the volume harvested, land ownership patterns, and land use indicates the importance of the small woodlot attached to the residence. Cross-referencing the relationships of land use and land ownership in Rhode Island shows that 49 percent of the wood cut by families (table 16) and 31 percent of all the cordwood obtained (33,700 of 109,000 cords in 1978) were from woodlots smaller than 25 acres which were owned by the harvesting family rather than by other private parties, the public, the forest industry, or a farming household (table 15). However, the small, family-owned woodlot supplies a larger than average portion of residential cordwood in Rhode Island when compared with the other New England States (table 16). Additionally, an estimated 47 percent of all wood obtained by households in Rhode Island (table 14, col. 4) is harvested from the 18 percent of commercial forestland which is in small, individually owned woodlots (table 14, col. 5).

In terms of lot size and amount of wood burned, residents using a small woodlot to supply their cordwood cut and burn less wood than those utilizing larger woodlots. The average volume of wood which Rhode Island households harvested from private, largely residential woodlots smaller than 25 acres averaged 1.5 cords whereas harvesting on larger private woodlots averaged about 2.5 cords. This pattern is consistent throughout New England.

3/ Information provided by the Northeast Solar Energy Center, Boston, Massachusetts, 1981.

Table 14--Source of cordwood harvested by residents for their own use, by land use, 1978, Rhode Island

Category of land use	Volume of cordwood harvested	Portion of all household-cut wood	Average volume cut per household	Portion of all wood acquired	Portion of commercial forestland in category 1/
	Cords	Percent	Cords	----Percent----	
Small private (smaller than 25 acres)	50,900	74	1.5	47	2/ 18
Large private (25 acres or larger)	17,900	26	2.5	16	2/ 57
Farm woodlot	--	--	--	--	3/ 6
Public land	*	*	*	*	8
Forest industry	*	*	*		-
Other land use	*	*	*	*	11
Total	68,800	100	1.7	63	100

Note: - = less than 0.5 percent; -- = none reporting in sample; * = insufficient sample size.

1/ See (3).

2/ See (4). Small private in (4) is defined as less than 20 acres; large private in (5) is defined as 20 or more acres.

3/ This category of commercial forestland includes all farmer-owned commercial forestland. Such forestland is not necessarily located on farms.

A series of questions in the fuelwood survey were designed to ascertain the degree to which household harvesting of cordwood is "threatening" commercial forestland in the State. 4/ During 1978, 73 percent of wood harvested by Rhode Island residents was cut from family-owned land and 13 percent was cut from a neighbor's land. In terms of land use, 90 percent of

4/ Commercial forestland is defined by the U.S. Forest Service as forestland producing or capable of producing a certain level of crops of industrial wood and not withdrawn from timber utilization. The definition excludes narrow strips of trees, trees in heavily settled areas, and trees in inaccessible areas.

wood harvested by households was cut from privately owned, basically residential woodlots, and 68 percent was obtained from privately owned woodlots of 25 acres or less (tables 14 and 15). Harvesting of fuelwood by households is concentrated on certain types of land. For example, of the 395,300 acres of commercial forestland in the State, 363,700 acres, or 92 percent, is in private ownership, with 81 percent (294,600 acres) of this land privately owned by individuals (4). Eighty-four percent of these owners have commercial forestland holdings of 50 acres or less, which represents 37 percent of the total privately owned forestland that is producing or capable of producing a reasonable crop of wood.

Table 15--Source of cordwood harvested by residents, by land use, 1978, New England

Land use	Maine	New Hampshire	Vermont	Massachusetts	Rhode Island	Connecticut
			Percent			
Small private (smaller than 25 acres)	53	49	33	48	74	64
Large private (25 acres or larger)	25	28	34	27	26	18
Farm woodlot	14	8	23	9	--	5
Public land	--	--	5	7	--	5
Forest industry land	4	6	3	3	--	--
Other	4	8	2	6	--	8
Total 1/	100	100	100	100	100	100

Note: -- = negligible amount.
1/ May not add to 100 because of rounding.

Table 16--Cordwood harvesting by residents on small, family-owned woodlots, 1978, New England

State	Volume of wood cut on family-owned, private woodlots of less than 25 acres	Portion of wood harvested by households on family-owned, private woodlots of less than 25 acres	Portion of total cordwood burned
	Cords 1/	Percent	
Maine	125,400	42	22
New Hampshire	114,000	48	29
Vermont	53,700	25	16
Massachusetts	175,900	31	21
Rhode Island	33,700	49	31
Connecticut	345,600	58	51
Total	848,300	44	29

1/ Rounded to nearest 100.

In order to indicate the impact of household cordwood harvesting on the forest resource, the 1979 survey recorded the extent to which respondents utilized professional forestry assistance in marking for harvest. In Rhode Island, only 3 percent of wood cut by residents was marked by a forester. This suggests that the wood cut from these lots is of such quality that it could not have been used for timber products (table 17).

RELATED ISSUES

The transition to wood energy has produced major changes in forest resource use, conventional fuel imports, household income, local employment, and household safety. This section places findings of the survey within the context of available State-level data on these issues.

Table 17--Use of professional foresters to mark wood cut by residents for their own use, 1978, Rhode Island

Category of land use	Volume of wood cut by residents	Portion of wood marked by forester
	Cords 1/	Percent
Small private	46,700	2
Large private	15,800	3
Farm woodlot	--	**
Public land	700	*
Forest industry land	700	**
Other	4,800	*
Total	68,700	3

Note: -- = negligible amount; * = insufficient sample size; ** = none reporting in sample.
1/ Rounded to nearest 100.

Economic Impact of Residential Wood Energy 5/

Rhode Island residents displaced $9 million of petroleum and about $1 million of electricity during 1980 through the substitution of wood energy for conventional heat sources (based upon home heating oil priced at $1.00 per gallon and electricity at $74 per 1,000 kWh in 1980).

The path of these savings through the local economy resulted in multiplied economic benefits, increasing local employment and household income.

Dollars not spent by households on imported fuel travel one ot two paths through the State economy. Some of the dollars purchase cordwood. During 1978, 40,000 cords of wood were

5/ A more detailed analysis involved the use of an input-output model will appear in a forthcoming report (see footnote 2).

purchased by 28,000 Rhode Island residents. The average price per cord (reflecting purchases of all forms of wood) was $66. Conservatively increasing the volume of wood purchased and the average price per cord to reflect increases since the survey date, the value of cordwood purchases during 1980 is estimated to be at least $5 million. This was paid by residents to the wood processing and harvesting industry, which in turn spent a high percentage of its gross income on the employment of local labor. The value of cordwood purchases by Rhode Island residents represents less than 6 percent of all dollars saved through wood energy substitution.

Most remaining dollars saved by substituting wood heat effectively increase household buying power. Some are spent to purchase wood-burning stoves and wood-harvesting equipment. Most of the remaining $42 million were spent by residents for a broad spectrum of household purchases, from food, clothing, and durables to vacations. These expenditures benefit the local economy much more than expenditures for fuel oil. Dollars paid to a local fuel oil distributor are largely sent out of the State in exchange for refined petroleum. Dollars spent for locally produced goods or services are often respent locally by the person supplying those goods or services, multiplying the effect of the original purchase.

Changes in Conventional Energy Demand

Wood has emerged as a major source of energy for the residential sector, considerably lowering demand for fuel oil and electricity. Rhode Island residents use 29 percent of all energy consumed in the State whereas, nationally, only 21 percent of energy is consumed by residences. 6/ This definition of the residential sector excludes gasoline used in automobiles. The U.S. Department of Energy estimates that Rhode Island households demanded 48 trillion Btu's during 1978, and that petroleum provided 59 percent of this. However, the Department of Energy did not collect or include data on residential wood energy consumption during this period.

Considered in the context of available Department of Energy data, together with the results of the Rhode Island Fuelwood Survey, wood energy constitutes 6 percent of the total energy demanded by the State's residences, with petroleum providing 55 percent (table 18). The energy content of the wood

6/ Residential sector consumption estimates are based upon 1978 data from the State Energy Data Report, U.S. Dept. Energy, Energy Information Adm., Apr. 1980, p. 337, revised to correct overestimation of LPG.

demanded by Rhode Island households during the winter of 1978-79 is estimated at 3.2 trillion Btu's according to data provided by the 1979 Rhode Island fuelwood survey (table 18).

Table 18-- Energy demanded by residences, by fuel type, 1979, Rhode Island

Energy form	Energy demanded 1/	Portion of all energy demanded
	Trillion Btu's	Percent
Petroleum	28.4	55
Natural gas	13.7	27
Electricity	6.2	12
Wood	3.2	6
Coal	--	--
Total	51.5	100

Note: -- = negligible amount.

1/ Estimates of residential consumption of conventional fuels are based upon the State Energy Data Report, U.S. Dept. Energy, Energy Information Adm., Apr. 1980, p. 337. Estimates are revised to correct for overestimation of LPG consumption and to remove generation and transmission losses included only for electrical energy. Residential electrical consumption as tabulated by DOE includes an additional 15.2 trillion Btu's. Approximately 44 percent of the indicated wood energy in Rhode Island is burned in fireplaces and provides little useful energy.

Wood burns at lower efficiencies than conventional fuels and therefore produces less useful energy per Btu of fuel. More efficient wood-burning devices would help households now using wood heat to consume less wood, but this would also encourage more households to convert to wood heat. The Rhode Island wood conversion rate of 0.29, which resulted from deriving 0.96 trillion Btu's of space heat from wood with a heat content of 3.2 trillion Btu's, is slightly lower than that obtained by residents in most of the other New England States. This lower conversion rate is associated with the relatively high portion of wood being burned in less efficient equipment, primarily fireplaces and open wood stoves.

Table 19--Energy from wood combustion in residences, by household group, winter, 1978-79, Rhode Island

Household group	Estimated volume of wood burned	Energy content of wood burned 1/	Wood-burning efficiency	Useful energy from wood	Equivalent fuel oil displaced 2/
	Cords	Trillion Btu's	Percent	Trillion Btu's	Mil. gals.
Owner-occupant	89,652	2.15	26	.556	6.16
Using only fireplace	48,031	1.15	10	.115	1.28
Using open wood stove	12,917	.31	30	.093	1.04
Using airtight wood stove	21,552	.51	50	.255	2.50
Using a wood furnace	7,152	.17	55	.093	1.03
Rental-occupant burning wood	12,172	.29	20	.06	.66
Second and seasonal homes burning wood	6,650	.16	3/ 5	.01	.09
Total	108,474	2.60	40	.626	6.91

1/ Cordwood measures in Rhode Island are for closely stacked wood, cut to stove length and split. On the average, a cord of wood used in Rhode Island can provide 24 million Btu's.

2/ Energy is calculated at 138,700 Btu's per gallon or 5.825 million Btu's per barrel. Oil-burning efficiency assumed at 65 percent. The conventional fuel savings estimated by survey respondents is well above this estimate which is calculated upon the basis of volume of wood burned. This estimate does not include savings in conventional energy which are correlated with use of wood-burning equipment, such as lowered thermostat settings and zonal heating.

3/ Efficiency of wood combustion in second homes is calculated from the reported mix of wood-heating appliances.

Wood used in Rhode Island residences displaces an equivalent of 7 million gallons of fuel oil (table 19, col. 5). This figure reflects the volume of fuel oil which would have been displaced by the volume of wood burned if wood had been substituted only for fuel oil. While a portion of this displaced energy is provided by other conventional fuels, fuel oil is by far the most common conventional fuel used in Rhode Island residences (table 20).

Table 20--Conventional fuel available to homeowners for space heating, 1979, Rhode Island 1/

Fuel	Homeowners
	Percent
#2 fuel oil	72
Electricity	2
Natural gas	24
Propane	1
Coal	1
Total	100

1/ Calculated upon a sample base of 244 homeowners.

Fuel oil and electricity represent the majority of the conventional energy being displaced by wood energy both because they are available to 74 percent of owner-occupant households and because they are relatively higher in cost per unit of energy.

The Rhode Island 1979 survey shows the heavy reliance on fuel oil and electricity as primary heating fuels (74 percent) by Rhode Island residents (table 20). This is a substantially larger proportion than primary fuel consumption in the Northeastern States (U.S. Department of Energy). 7/ In these

7/ In addition to New England, States in this region include Maryland, Delaware, Pennsylvania, New York, and New Jersey.

States, the primary fuels of fuel oil and kerosene supply 47 percent of dwellings. However, natural gas, which can be delivered at low cost by pipe to more densely settled areas, supplies 41 percent of households. Electricity supplies 11 percent and propane supplies 1 percent. This relationship explains why the residents of Rhode Island, on the average, substitute proportionately more wood energy for conventional fuels than the other residents in the Northeast.

Cordwood Demand and the Forest Resource

The relationship between the forest resource and cordwood demand gives rise to two central questions:

1. Will the satisfaction of fuelwood demand lead to overharvesting or deterioration of the resource?

2. Will the supply of cordwood constrain the increasing use of cordwood as a substitute for conventional fuels?

Residents obtain cordwood both by purchasing and by selfcutting. Analysis must consider these two sources separately as well as their interaction. The wood supplied by residents harvesting for their use largely depends on privately owned small woodlots, which are usually a part of the residence. A considerable percentage of these woodlots are not large enough to provide all of the wood required by the household on a sustainable yield basis. As a result, after several years of harvesting trees considered excess stock, many residents may begin to purchase an increasing portion of their cordwood to prevent destruction of their woodlots.

A proportion of the cordwood marketed is sold by enterprises whose primary employment is in supplying either pulp or timber products. These enterprises are able to separate trees and sell them to the markets that represent the highest valued use for their product. These firms are competitive at current market prices. Integration of wood products within a harvesting operation makes cordwood production dependent upon the harvesting for other wood products since a smaller proportion of profit is derived from fuelwood. This relationship is limited to current price relationships.

Production efficiency is also limited by the size of woodlots. Small woodlots, which characterize most of New England, result in higher transportation costs of harvesting equipment to the site, and higher administrative costs to the harvester. Small woodlot owners are usually more concerned with environmental controls (4), which increase the cost of harvesting. Quality of most timber stands in the State is relatively poor. Much of the past timber harvesting resulted in highgrading, wherein the best trees were harvested and the poorest were left. Remaining trees became parent stock for much of the present tree populations and, as a result, present stands are of lower quality, which decreases production efficiency in terms of

annual growth. Cordwood use and the resulting market demand provide an opportunity to harvest this lower quality timber and could improve overall quality of remaining timber stands.

Transportation of cordwood also affects local supply. In areas which have a few large woodlots and a limited number of sawmills that use cordwood co-products, local residential demand raises cordwood prices and imported wood provides much of the supply. Cordwood is commonly transported up to 100 miles to reach higher priced markets. Many densely settled areas of New England that possess limited forest resources now burn more wood than the forests within the area can supply in the long term, given current management practices.

Cordwood in these areas of intense use will eventually be supplied from two sources: wood locally available on a sustainable basis and wood purchased from suppliers operating in a much larger market region.

Several broadbrush efforts have been made to estimate the potential supply of wood energy within the next 20 years. These estimates largely depend upon the area of land in forest and current forest conditions (table 21). An estimate of annual available biomass for Rhode Island was made by the Biomass Subcommittee of the New England Energy Congress (5). That estimate included a renewable yield (cull increment, annual mortality, annual thinning of poletimber stands, mill residues, and logging residues) and a non-renewable yield (land clearing, existing cull, and one-time thinning) which would reduce the overstocked forests over 20 years. Estimate of total wood energy potential per year in Rhode Island is given

Table 21--Forestland use in New England

State	Commercial forestland	Productive reserved	Unproductive 1/	Proportion of land in forest
	1,000 acres			Percent
Rhode Island	395	9	--	60.2
Connecticut	1,806	2/ 30	25	69.7
Maine	16,894	221	634	89.7
Massachusetts	2,798	104	50	58.9
New Hampshire	4,692	2/ 55	238	86.2
Vermont	4,430	2/ 44	20	75.7
Total	31,015	463	967	80.5

Note: -- = negligible amount.
1/ Incapable of producing 20 cubic feet per acre per year of industrial wood (all roundwood products except fuelwood).
2/ Includes some acreage used for Christmas tree production.
Source: U.S. Forest Service resource bulletins NE-26, NE-36, NE-43, and NE-46.

by the final report of the New England Energy Congress as 9 x 10^{12} Btu's, which is an equivalent of 375,000 cords per year (5). The committee also noted the present lack of an established supply network as the major limit to biomass supply. Another estimate of the annual energy potential that could be derived from Rhode Island's biomass was made by Glidden and High. This estimate which includes rough and rotten standing stock depleted over 20 years, annual cull increment, annual mortality, annual net growth, logging residues, and manufacturing residues amounted to 10 x 10^{12} Btu's (2). The 1979 residential cordwood demand within the State is estimated at 109,000 cords (acquired during 1979). This is only 30 percent of the above mentioned equivalent cord estimate, suggesting that Rhode Island's wood energy demands are well below its current wood energy supply potential.

Safety and Wood Energy

Resurgence of wood energy has resulted in an increased incidence of chimney and housefires. Wood-burning respondents indicated whether they had experienced a fire within the last 6 years and how the fire started. As a survey of all households, rather than a survey focused on households experiencing a hazardous event, the survey is useful in estimating the frequency of fires. Other surveys made by Shelton (8) and Peacock (7) have focused on those experiencing fires. These efforts provide a better sample for understanding causes of housefires related to use of stoves and furnaces fueled by wood.

Somewhat under 1 percent of Rhode Island households experience a housefire associated with the burning of firewood each year. Two percent of households burning wood (2 observations of 88 sample points) experienced a housefire associated with wood use during the 6-year period (1973 to 1979). For homeowners using an airtight wood stove, 6 percent (1 of 18) experienced such a fire during the same period. The frequency of housefires caused by burning wood in Rhode Island is below the 5 percent of all New England wood-burning households that have experienced such a fire during the 6-year period.

Some 67 percent of those households using airtight wood stoves had installed a smoke detector; 51 percent of non-wood-burning households had installed them. The installation rate of smoke detectors, together with the fact that 85 percent of households using airtight stoves clean their chimneys at least once a year, suggest that this group of wood-burning households recognizes the increased safety problems associated with wood energy.

Over 70 percent of wood- or coal-related chimney or housefires result from faulty installation (8). Poor maintenance or inadequate clearance caused 16 percent of such fires, operator error caused 11 percent, and faulty equipment caused 2 percent. Peacock confirms faulty installation as the primary cause of fires, and lists nine major causes of accidents related to wood burning (7):

1. Use of unvented equipment inside a dwelling.
2. Installation of wood-burning equipment too close to combustible framing and furnishings.
3. Placement of flammable solids and liquids too close to wood-burning equipment.
4. Use of flammable liquids to kindle a fire.
5. Overloading of wood-burning equipment, leading to operation well beyond design limits.
6. Ignition of clothing or other fabrics during loading, unloading, cleaning, or use of wood-burning equipment.
7. Contact burns received from hot surfaces of wood-burning equipment.
8. Use of defective or improper chimneys.
9. Ignition of creosote and carbon deposits on the inside of chimneys leading to chimney fires.

Peacock reported that 94 percent of the accidents occur in one and two-family dwellings. About 55 percent of the accidents were related to the wood-burning unit itself, 35 percent resulted from malfunction of the chimney, and 10 percent resulted from the chimney connectors on freestanding stoves.

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APPENDIX I:
SURVEY METHODS 1/

Discussion of Survey Bias

Telephone surveys of Rhode Island households were conducted in 1979 as a means to estimate the volume of cordwood consumed by residences during the winter of 1978-79. Telephone surveys, like other types of surveys, have survey bias. Bias is the difference between the estimated value of a statistic obtained by random sampling and the true value. There are certain conditions giving rise to bias in any survey technique; the result may be an estimate (for example, volume of cordwood burned) that is much different than the true value (in this example, volume of cordwood actually burned). There are a number of survey biases associated with telephone surveys, as well as biases that result from "uncheckable" information. During the design phase, eight potential forms of survey bias were identified, and where necessary, steps were developed to insure minimum influence by these biases. These sources of survey bias were:

1. Households without telephones could not be interviewed. Thus, there was no means to ascertain whether their wood-burning practices differed from those households interviewed.

2. Households with unlisted telephone numbers could not be selected for interview since published telephone lists were used as the surveyed population.

3. Hard-to-reach or not-at-home households may burn less wood since no one is at home during typical working hours.

4. Households that refuse to be interviewed create a possible source of bias.

5. Households that refuse to answer individual questions also create a possible source of bias.

6. The system through which volunteer enumerators were chosen in several States resulted in a potential source of bias in that one geographical area may have had a higher number of sample points and thus may have created an over-weighting of data from that area.

1/ A detailed description of methods will appear in a forthcoming report (see text footnote 2).

7. In some States, the wood use of rental households not paying separately for their own heating fuel was estimated with data from other States where this household group was interviewed.

8. A final form of bias is the under- or overestimation of actual cordwood volume reported by each respondent.

In order to insure precise estimates, steps were taken to first identify whether the potential source of bias was present and whether the bias would have a significant impact upon estimated statistics. Coefficients were developed to adjust the gross estimates derived from survey response in order to mitigate the bias impacts. Methods employed in developing the adjustment coefficients included subsurvey, resurvey, and stratification of response. The potential biases were analyzed as follows:

1. Households without telephones: This may be the least understood source of bias since the use of a telephone survey precludes the inclusion of this houshold group, and as a result, it is impossible to estimate the volume of fuelwood that this group consumes. However, given the fact that a very small percentage of households are without phones, that they tend to be located in rural areas, and that there is no evidence that this household group has something other than a random distribution of wood-burning characteristics, it was assumed that the bias resulting from not interviewing this group was minimal. Any bias stemming from this group would probably result in an insignificant underestimation of total cordwood consumption. Similarly, presence of households with more than one telephone may result in bias, but this group's wood use is expected to be similar or slightly less than that of the one-telephone household.

2. Households that have unlisted (unpublished) telephone numbers may constitute up to 10 percent of households. Generally, this group of households tends to be concentrated in urban areas and to be heavily female-headed. In order to estimate the potential amount of bias stemming from this group, a subsurvey was conducted in Maine to determine if this group was significantly different in their wood-burning characteristics. An

analysis of a "plus-one digit" dialing survey suggested little bias from this group. 2/

In addition, Clyde L. Rich, who has investigated this problem, notes:

> Because many of the differences are small and the non-published population is small, samples drawn from telephone directories have virtually the same demographic characteristics as samples which include non-published numbers. 3/

3. Hard-to-reach household bias was estimated by analyzing separately the data derived from households which responded on the third or later call. This analysis indicated that a significant bias was present. As a result, gross cordwood volume estimates were reduced by 9 percent.

4. Bias resulting from households that refused to participate in the survey was estimated by recalling them. On the recall, it was explained why they were being called back. Recalls were very effective in that very few of the households declined to answer the questions. Analysis of that data indicated that no bias was present.

5. Households that refused to answer specific questions contributed no bias in that their refusals were centered upon questions dealing with socioeconomic information (age and sex of head of household, household income, etc.) and not upon questions dealing with household wood-burning characteristics.

6. Through geographically stratifying survey estimates, bias resulting from an uneven distribution of sampled households was negated.

7. Except in Vermont, rental households who did not pay for their heat separately from their rental payment were not surveyed because:

   a. The vast majority are apartment dwellers with little opportunity to use wood.

2/ "Plus-one digit" dialing refers to a process where the last digit of a published number is increased by one, and then called.

3/ Clyde L. Rich, "Is Random Digit Dialing Really Necessary?" J. Marketing Research, Aug. 1977.

b. Unless heating costs are separated from the rental payment, such households have little economic incentive to convert to a nonconventional fuel.

The minimal wood use of this group was estimated for the other New England States through use of data from the Vermont survey.

8. Potential bias from faulty reporting of cordwood volumes was approached through a double survey which compared results of the standard questionnaire with one which contained an indepth discussion of the cord and other wood measures. That survey took place in the five counties surrounding Burlington, Vermont. An overestimation of 9 percent occurred. Thus, gross estimates less the adjustments for hard-to-reach households were reduced by an additional 9 percent. While it is certainly recognized that a ground-truth check would have been ideal, budget and time constraints precluded such an effort. 4/

Survey Sample Design

The six States had different spatial objectives relative to the survey. Massachusetts, for example, wished to estimate wood use on a county-by-county basis, whereas Rhode Island and Vermont wished to have data only on a Statewide basis. New Hampshire collected sufficient data to provide estimates for each of three regions of the State. All States collected data from enough sample points to permit a rigorous statistical assessment of residential wood use at the State level (App. table 1).

Telephone numbers were generated in such a way as to assign each household an equal probability of being surveyed. The selection procedure used telephone books to find noncommercial household telephone numbers in a randomly started, standardized manner. Selected numbers were pursued, within reason, according to a series of call-back rules until a survey was completed. If any number could not be surveyed, it was replaced with another number found by continuing the standardized procedure.

4/ Ground-truth check could be conducted as follows: A subsample of the sampled households is asked how many cords presently in inventory. Then, the interviewer would travel to those households and actually measure the wood stacks to determine bias of household estimates.

Appendix table 1--Total sample collected, by State, 1979

State	Number of usable questionnaires
Maine	1,152
New Hampshire	813
Vermont	555
Massachusetts	2,359
Rhode Island	301
Connecticut	446
Total	5,626

Survey Precision in Rhode Island

Interviewing in Rhode Island to determine residential wood use during the winter of 1978-79 resulted in a sample of 300 respondents (App. table 2). Stratification by tenure and county allowed use of census data to correct for sampling bias. Use of stratification precluded use of 1 response which had not recorded all information required to stratify. Combination of survey and census data resulted in the estimate of households by type of wood-burning apparatus (App. II). Precision of this estimate is determined by the percentage of all respondents of a strata using a form of wood-burning apparatus and the sample for that strata.

Appendix table 2--Stratified sample of household respondents, Rhode Island, 1979

Group	Sample size
Second or seasonal home occupant not burning wood	-
Second or seasonal home occupant burning wood	-
Rental household with heat included not burning wood	-
Rental household with heat included burning wood	-
Rental household paying for heat separately not burning wood	46
Rental household paying for heat separately and burning wood	3
Owner-occupant household not burning wood	166
Owner-occupant household using only an open fireplace	46
Owner-occupant household using an efficient fireplace	10
Owner-occupant household using a traditional open wood stove	9
Owner-occupant household using an airtight wood stove	18
Owner-occupant household using a central wood-fired heating system	2
Total	300

Reported consumption of cords by type of apparatus allows estimation of the residential use of wood based upon the above estimated household group populations (App. table 3). Reported volumes burned are corrected for identified faulty response bias associated with poor understanding of the cord measure. The resulting average volume burned by apparatus type has a precision or standard error related to the distribution of reported responses together with the sample size.

Appendix table 3--Precision of average volume burned by apparatus for owner-occupant households, winter, 1978-79, Rhode Island

Apparatus	Total respondents	Average volume burned per household	Standard error of average	Sample for average volume
	Number	--------Cords--------		Number
Open fireplace	46	1.09	.23	44
Efficient fireplace	10	1.06	.30	9
Traditional wood stove	9	1.97	.34	9
Airtight wood stove	18	1.72	.31	16
Wood furnace (combinations incl.)	2	5.46	2.73	2

The resulting estimate of residential wood use has a level of precision or standard error which is a function of both the standard error of the percentage of households within a group and the standard error of the average volume burned by that group. The standard error for the Rhode Island Statewide estimate of cordwood use by residents during the winter of 1978-79 is 14,529 cords or 14 percent of the 108,474 cords burned (App. table 4).

Appendix table 4--Standard errors for estimates of fuelwood burned, Rhode Island, winter, 1978-79

Wood-burning group	Bristol	Kent	Newport	Providence	Washington	Statewide
Second home	107	192	446	88	1,652	1,733
Rental with heat included	174	576	491	4,471	349	4,552
Rental paying separately	196	652	555	792	395	1,247
Owner-occupant using an open fireplace	1,646	2,829	1,787	6,882	1,960	8,018
Owner-occupant using an efficient fireplace	1,019	1,043	982	2,649	895	3,304
Owner-occupant using a traditional wood stove	0	2,364	1,097	4,021	1,430	5,001
Owner-occupant using an airtight wood stove	1,960	2,957	1,904	3,916	1,765	5,887
Owner-occupant using a central wood furnace	0	0	0	0	7,139	7,139
Standard errors for counties	2,769	4,921	3,123	10,281	7,985	14,529

APPENDIX II: TABLES OF BASIC FINDINGS

The following tables present basic findings of the Rhode Island survey of residential wood use during the winter of 1978-79. Information on wood burned, purchased, and harvested by households is comparable to estimates to be published for all other New England States. Together, these estimates constitute an integrated estimate of residential wood use by county for New England.

The household groups used in appendix tables 5 and 6 are defined as follows:

Group 1 - Second or seasonal homes not burning wood
Group 2 - Second or seasonal homes burning wood
Group 3 - Rental household with heat included not burning wood
Group 4 - Rental household with heat included burning wood
Group 5 - Rental household paying for heat separately not burning wood
Group 6 - Rental household paying for heat separately and burning wood
Group 7 - Owner-occupant household not burning wood
Group 8 - Owner-occupant household using only an open fireplace
Group 9 - Owner-occupant household using an efficient fireplace
Group 10 - Owner-occupant household using a traditional wood stove
Group 11 - Owner-occupant household using an airtight wood stove
Group 12 - Owner-occupant household using a central wood furnace

The household groups used in appendix tables 7 and 8 are defined as follows:

Group 1 - Second or seasonal homes not burning wood
Group 2 - Second or seasonal homes burning wood
Group 3 - Rental household with heat included not burning wood
Group 4 - Rental household with heat included burning wood
Group 5 - Rental household paying for heat separately not burning wood
Group 6 - Rental household paying for heat separately and burning wood
Group 7 - Owner-occupant household not burning wood
Group 8 - Owner-occupant household using only a fireplace
Group 10 - Owner-occupant household using a wood stove or furnace

Appendix table 5--Number of households stratified by wood-burning category, type, and county, Rhode Island, winter, 1978-79

	Bristol	Kent	Newport	Providence	Washington	Totals
Group 1	158	284	690	131	2444	3707
Group 2	263	473	1150	218	4074	6178
Group 3	2928	9709	8269	75317	5881	102104
Group 4	225	747	636	5794	452	7854
Group 5	987	3272	2787	25382	1982	34409
Group 6	64	213	182	1655	129	2244
Group 7	5021	23300	6620	90361	10076	135378
Group 8	2510	5825	3862	20459	3599	36255
Group 9	837	832	1103	4262	720	7754
Group 10	0	1664	552	4262	720	7198
Group 11	1673	3329	2207	5115	1439	13763
Group 12	0	0	0	0	1439	1439
Totals	14665	49648	28057	232956	32956	358282

Appendix table 6--Volume of wood burned by the residential sector, in cords, Rhode Island, winter, 1978-79

	Bristol	Kent	Newport	Providence	Washington	Totals
Group 2	283	509	1238	235	4386	6650
Group 4	186	618	527	4798	375	6504
Group 6	163	539	459	4181	326	5668
Group 8	2742	6362	4218	22347	3931	39600
Group 9	910	905	1200	4634	783	8431
Group 10	0	2987	990	7649	1292	12917
Group 11	2621	5212	3456	8009	2254	21552
Group 12	0	0	0	0	7152	7152
Totals	6904	17133	12087	51852	20497	108474

Appendix table 7--Volume of wood purchased by the residential sector, in cords, Rhode Island, winter, 1978-79

	Bristol	Kent	Newport	Providence	Washington	Totals
Group 2	72	131	317	60	1124	1705
Group 4	93	309	263	2399	187	3252
Group 6	25	82	70	640	50	867
Group 8	1641	4079	1607	10907	1397	19631
Group 10	2425	3783	914	6687	1013	14822
Totals	4257	8385	3171	20693	3772	40278

Appendix table 8--Volume of wood harvested by households for their own use, in cords, Rhode Island, winter, 1978-79

	Bristol	Kent	Newport	Providence	Washington	Totals
Group 2	174	313	762	145	2699	4092
Group 4	186	618	527	4798	375	6504
Group 6	55	181	154	1403	110	1902
Group 8	1960	1949	3256	17079	3388	27631
Group 10	1268	5069	2090	7105	13112	28645
Totals	3643	8131	6789	30529	19683	68774